TRANSPORT OF REACTIVE ANIONS AND CATIONS IN A VOLCANIC SOIL: EXPERIMENTS AND MODELLING

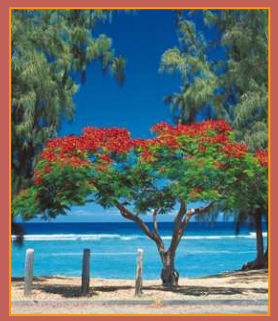
Sansoulet J.,

Feder F., Simunek, J. Findeling, A., Doelsch, E., Bochu V.

August, 26 2008

University of Technology, Vienna

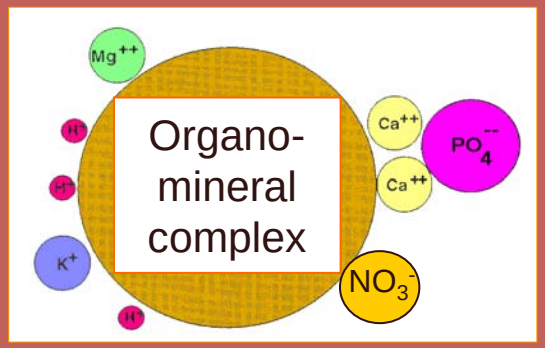
Introduction



« La Réunion » Island

Agricultural crop fields are commonly amended with **organic products** that contain nitrogen and heavy metals, such as rich pig manure, which can lead to **soil and groundwater pollution**.

Source : Feder F.



Volcanic ash **soil with variable charges** could potentially develops **anion and cation exchange capacities** which could interact with anions and cations during the transport.

Introduction

→ The **ability to predict accurately water flow and solute transport** into and through a Nitisol is essential for an effective management of agricultural practices and the control of environmental risks.

Our objectives are :

❖ To study the **impacts of a pig manure amendment** on the **retention** and **flux of chemical elements – anions and cations** into volcanic ash soil columns

❖ To simulate ions transport with a **biogeochemical transfer model** (Ca, Na, K, NO3, Cl, Zn, Cu, Mg, Fe, Mg)

Material and Method

- Over a **120-days** period
- **3 large columns (85 x 40 cm)** from a Nitisol : one untreated column (control) and two amended with pig manure
- **Soil moisture regimes** were continuously monitored at four depths and analyzed : Ca, Na, K, NO_3, Cl, Zn, Cu….

Untreated **Pig manure amendment**

+ regular amounts of water of 200 mm a week

17.5 cm : Microtensiometers, TDR and Redox

55 cm : Microtensiometers, TDR and Redox

30 cm : Microtensiometers, TDR and Redox

85 cm : Microtensiometers, TDR and Redox

Datalogger

Collectors

Material and Method

HP1 – Coupled HYDRUS-1D and PHREEQC model

Šimůnek et al. 2006, 2008

Šimůnek et al. 2006

Parkhurst & Appelo 1999

This code contains modules simulating :

- **transient water flow in variably-saturated media** — Richards equation
- **the transport of multiple components**
- **mixed equilibrium/kinetic biogeochemical reactions**
  Sorption surfaces based on thermodynamic equilibrium, kinetic, or mixed equilibrium-kinetic reactions
- **heat transport**

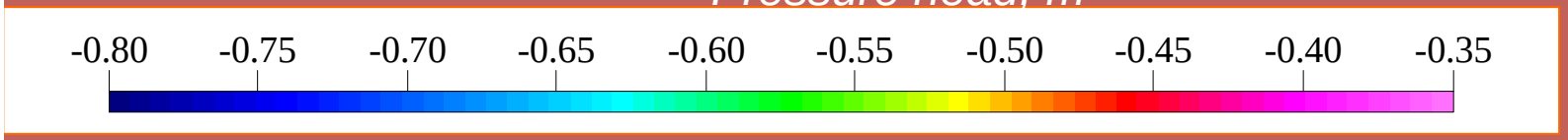
Advection-dispersion equations

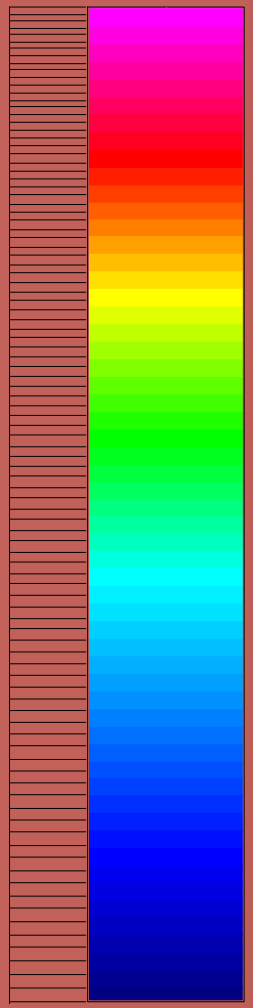
Material and Method

We defined :

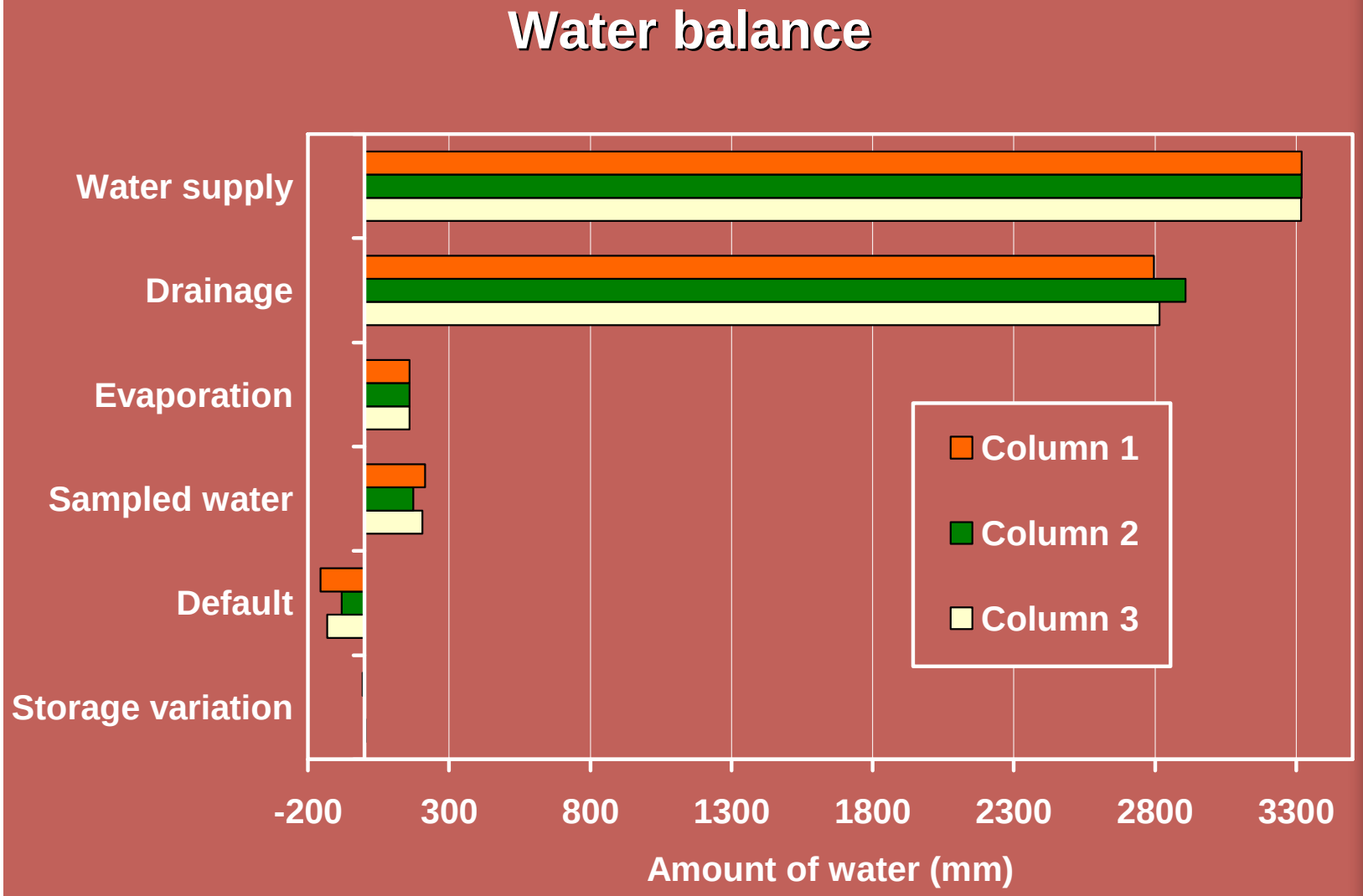
- **4 layers** with hydraulic (water retention curve and *Ksat*) and chemical properties (retention and nitrification)
- **Initial conditions** : water and solutes
- **Inputs** : pig manure and irrigation
- Evaporation
- **Observations nodes** (inverse procedure)

→ Example : Water initial conditions





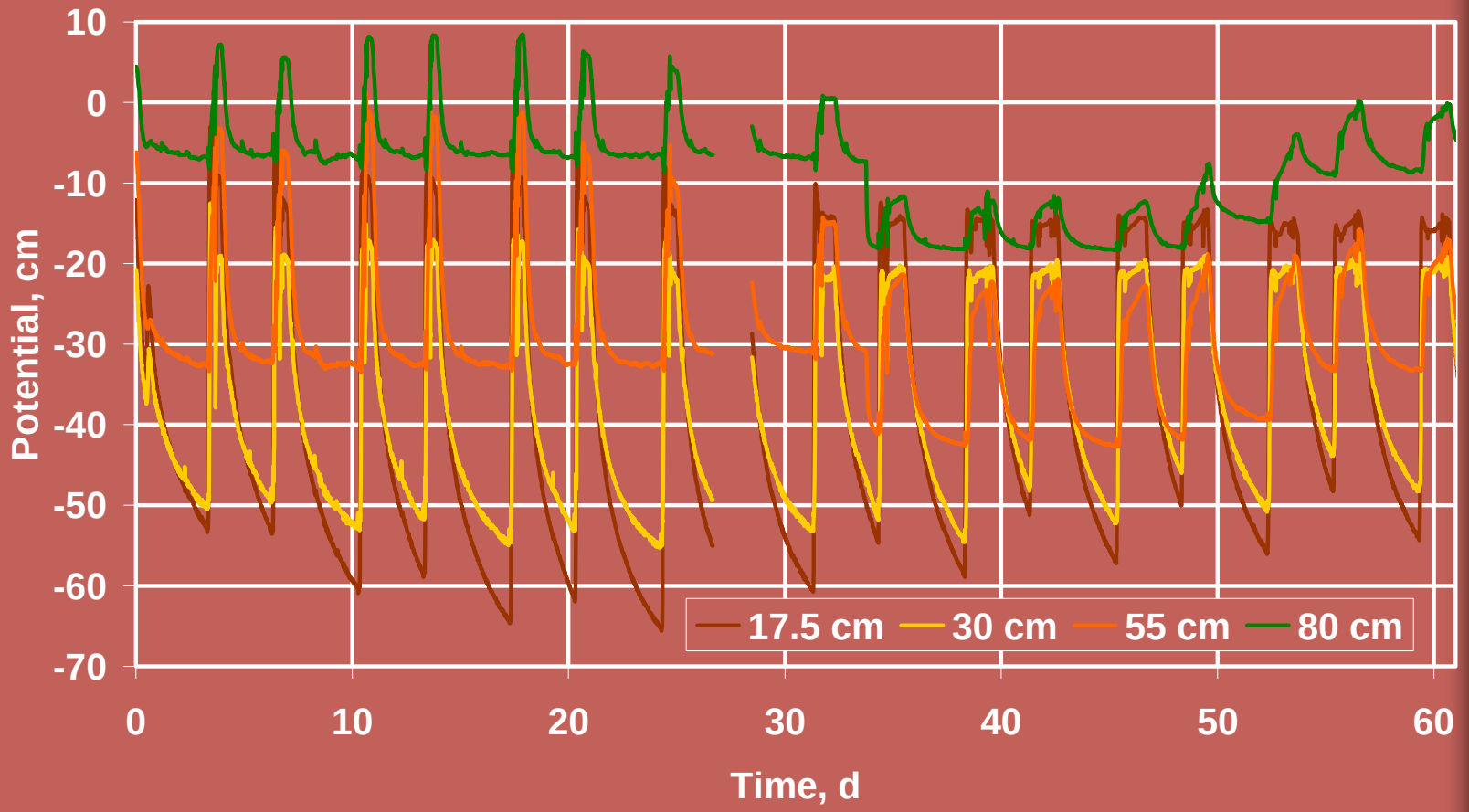
Results


Water balance
Water supply
Drainage
Evaporation
Sampled water
Default
Storage variation
Column 1
Column 2
Column 3
-200
300
800
1300
1800
2300
2800
3300
Amount of water (mm)

Results

Inverse procedure :

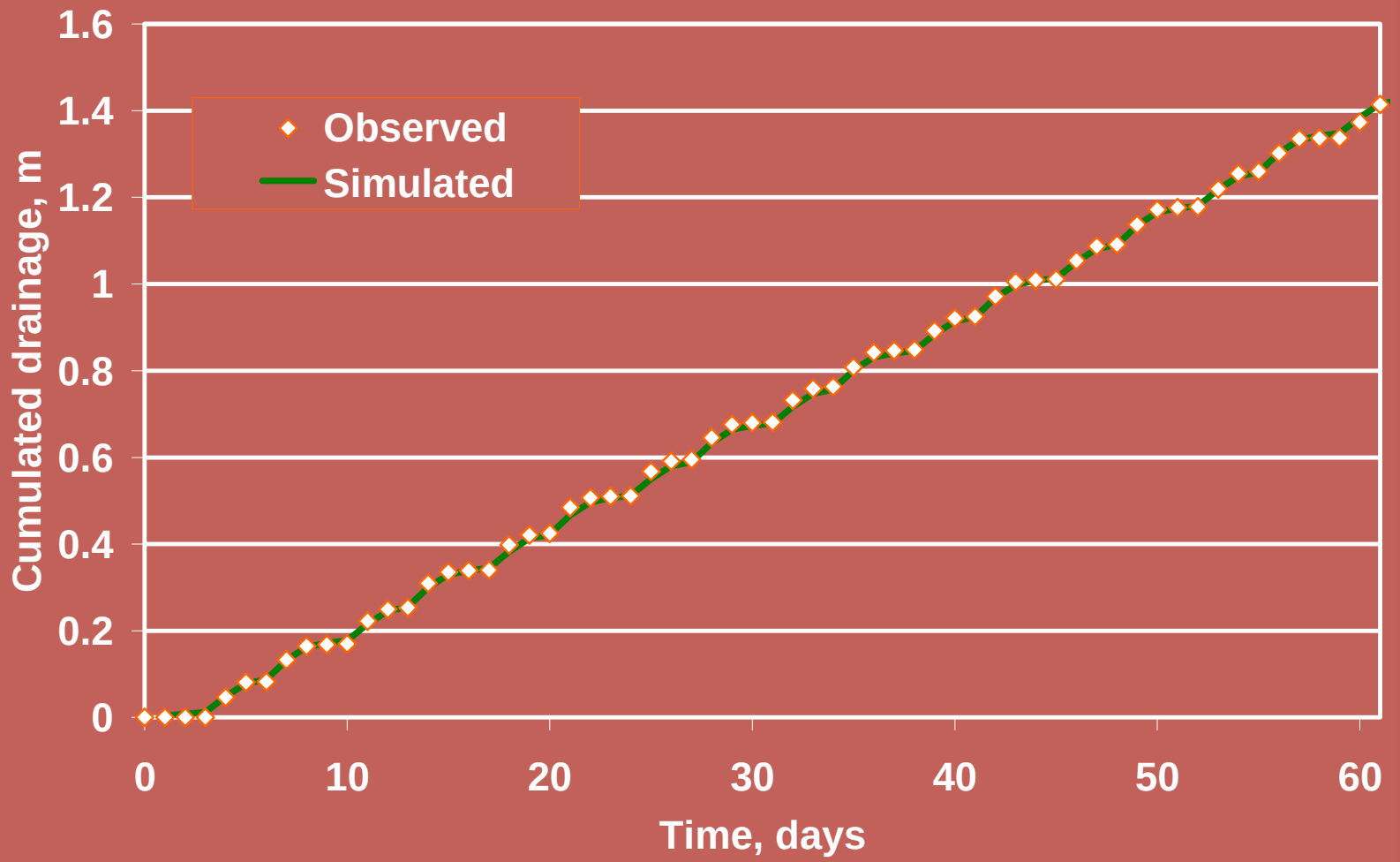
Observed pressures head used as a part of objective function



Results

Inverse procedure :

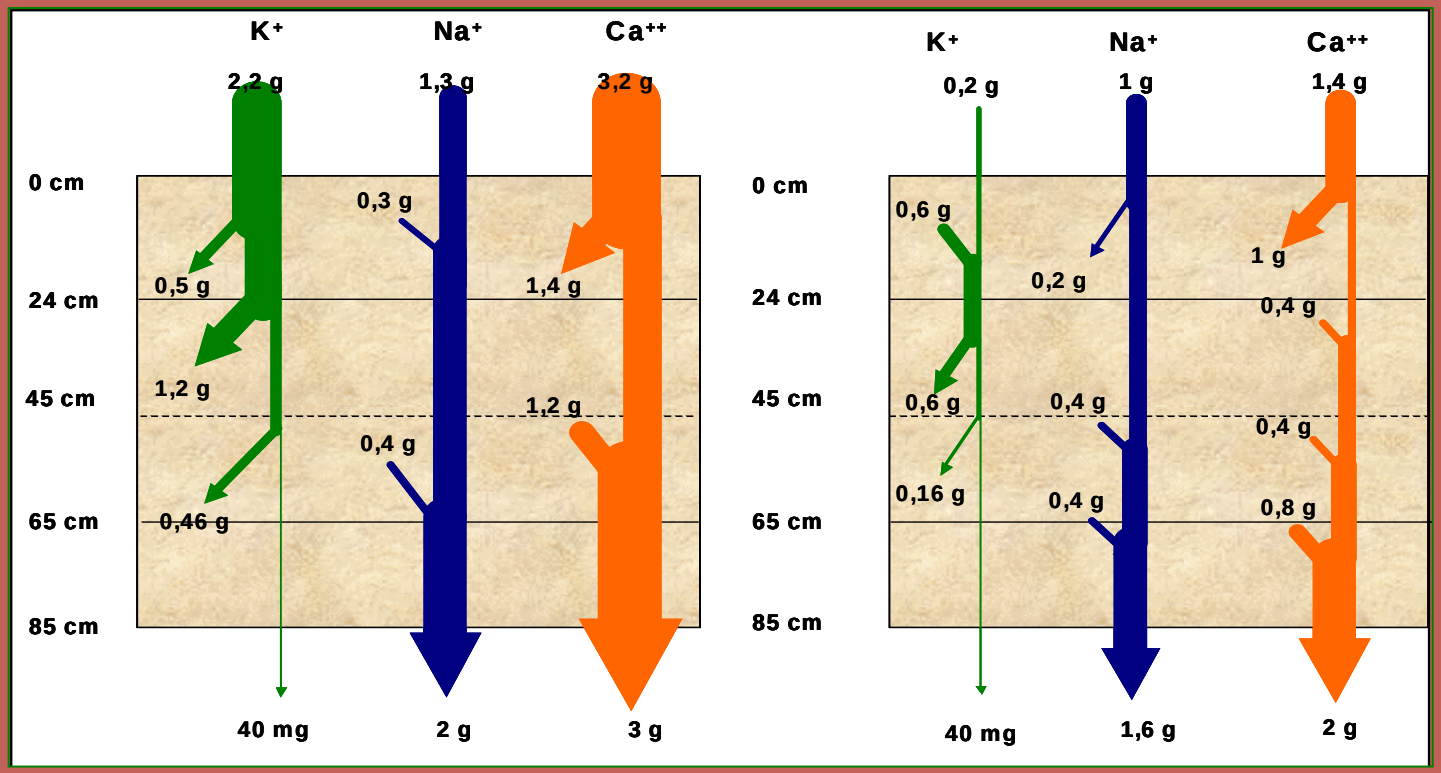
Observed cumulated drainage used as validation



Results

Retention and fluxes of K^+, Na^+ and Ca^{++}

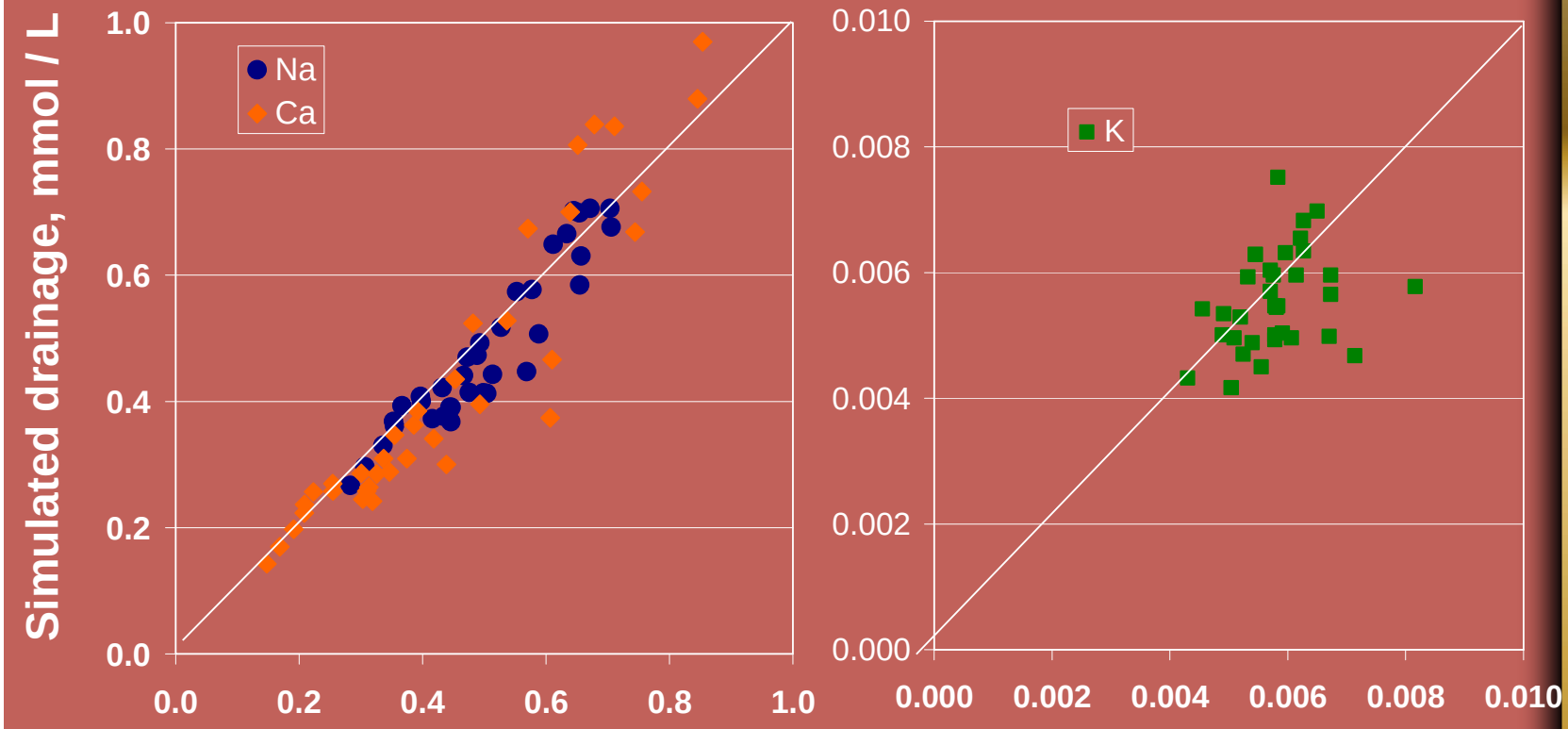
Amended with pig manure



Control

Calcium and potassium interacted with cation exchange complexe ; sodium were less adsorbed and thus more mobile

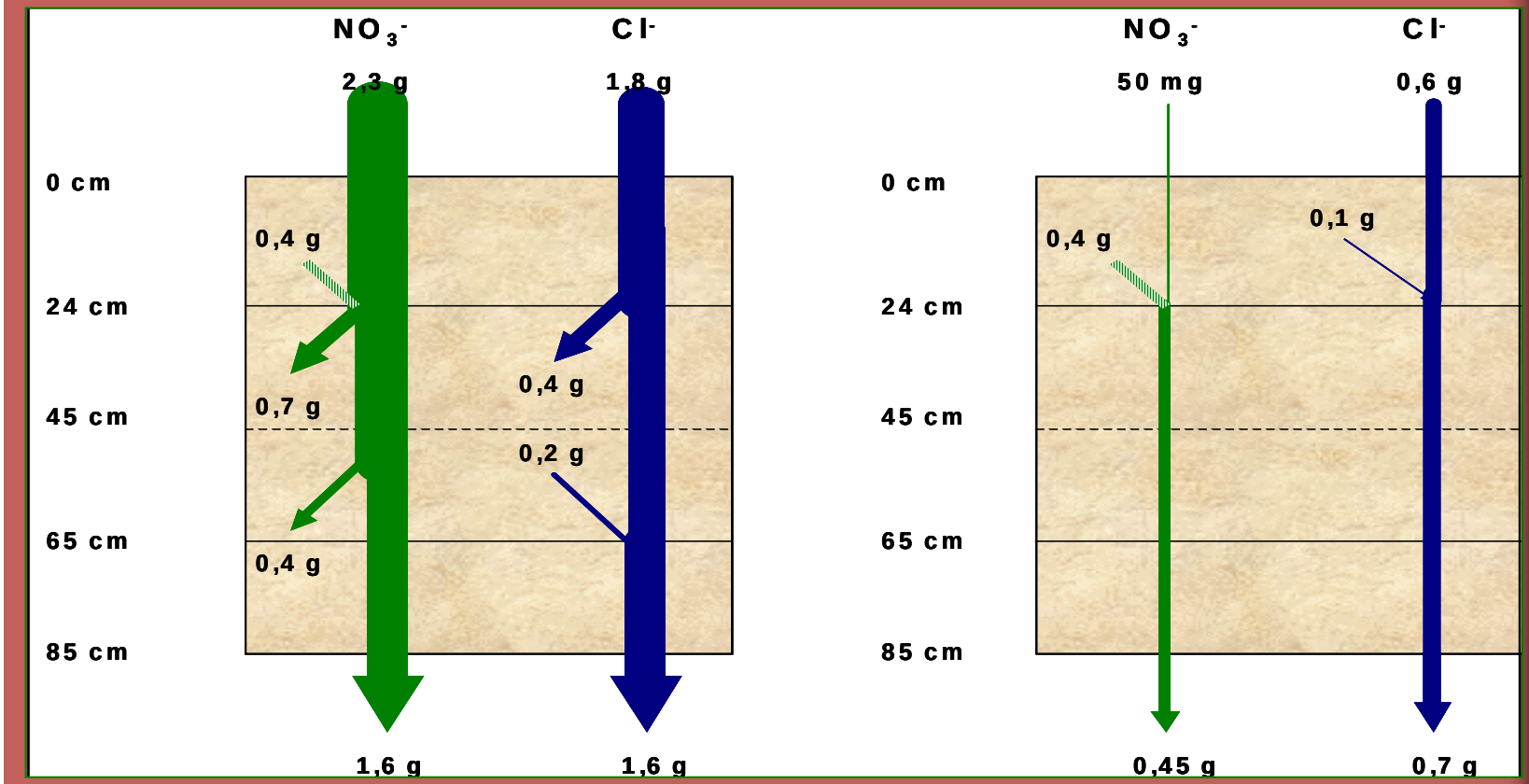
Results


Simulated drainage, mmol / L
1.0
0.8
0.6
0.4
0.2
0.0
Na
Ca
0.0
0.2
0.4
0.6
0.8
1.0
0.010
0.008
0.006
0.004
0.002
0.000
K
0.000
0.002
0.004
0.006
0.008
0.010
Measured drainage, mmol / L

Results

Retention and fluxes of NO_3^- and Cl^-

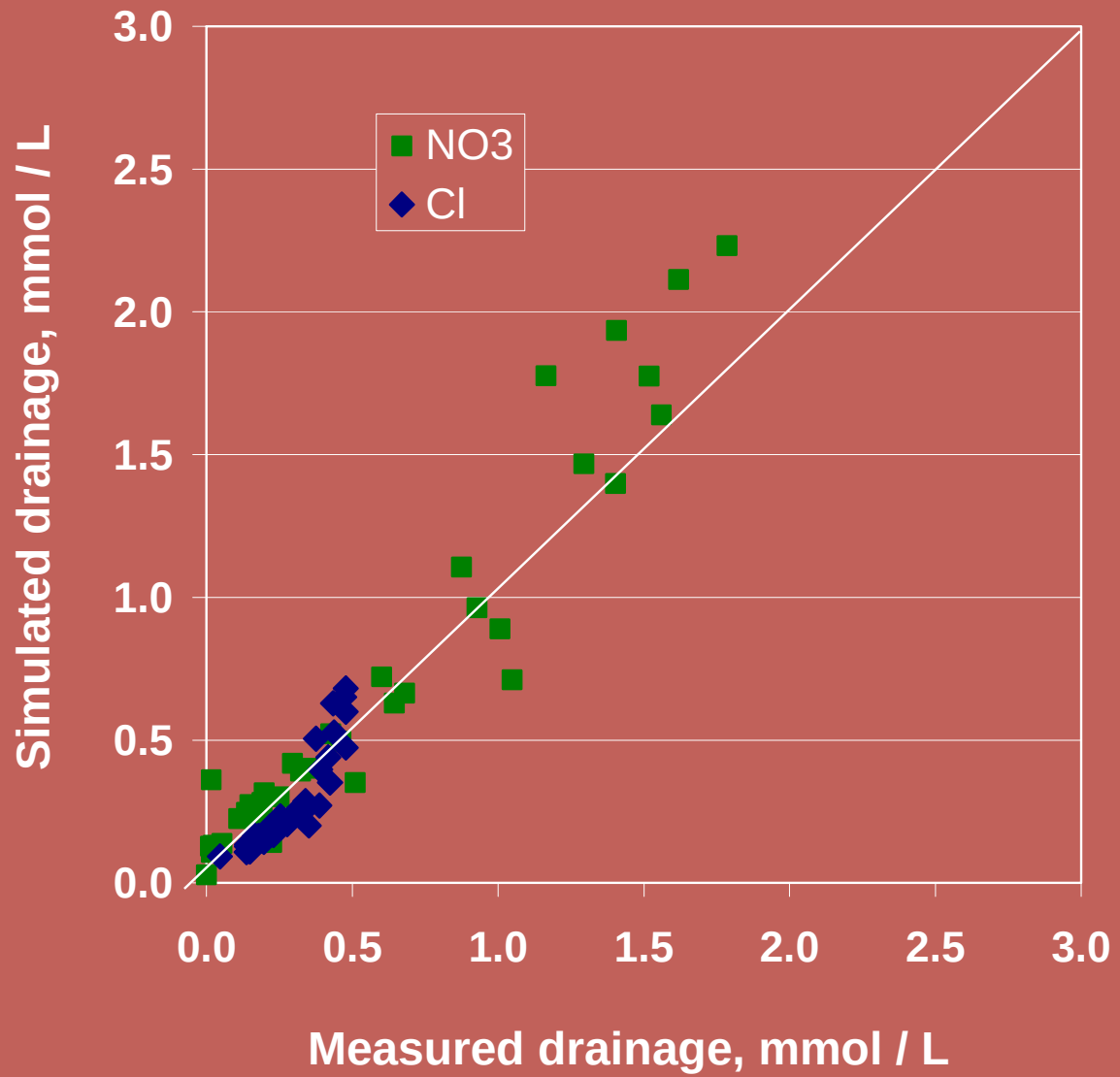
Amended with pig manure



Control

Nitrate also interacted with anion exchange complexe ;
chlorides were less adsorbed and thus more mobile

Results


NO3
Cl
Simulated drainage, mmol / L
Measured drainage, mmol / L
0.0
0.5
1.0
1.5
2.0
2.5
3.0

Results

Difficulties…

❖ **Cu and Zn could not transfer in depth** :

Cu
Zn

✓ they could not be decomposed during the experimental period

✓they did largely interact with the first horizon of the soil

❖ **Geochemical model is a somewhat complex** with respect to the number components, e.g. all these heavy metals as Cu, Mn, Fe, Zn…so there were **convergence problems**

→ no possibility to model all the components

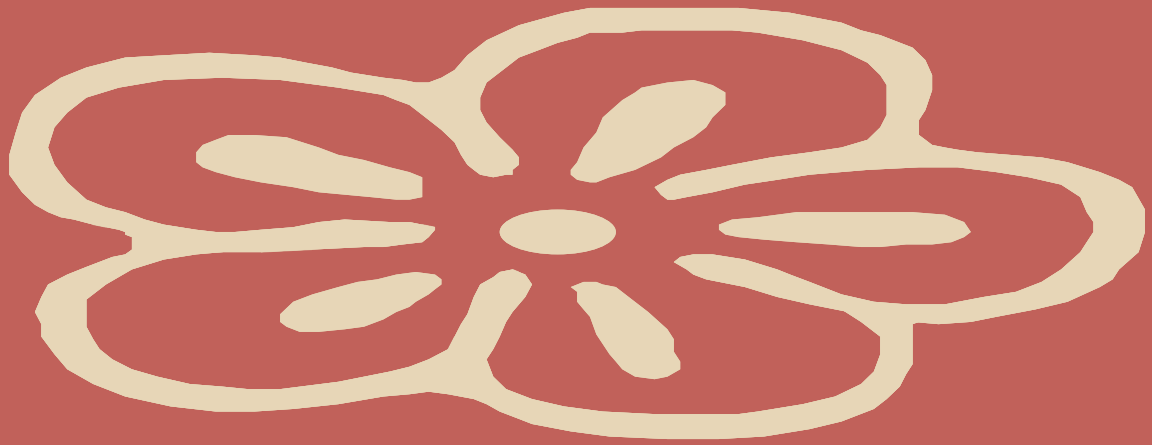
Conclusion

Experimental and modelling results showed that there was an **interaction between anions and cations in the soil exchangeable phase**.

These results emphasized the **specific hydraulic and exchange properties of a volcanic soil** under tropical conditions.

These specific features must be taken into account to properly predict the fate of organic matter and inorganic pollutants in the soil and down to the groundwater.

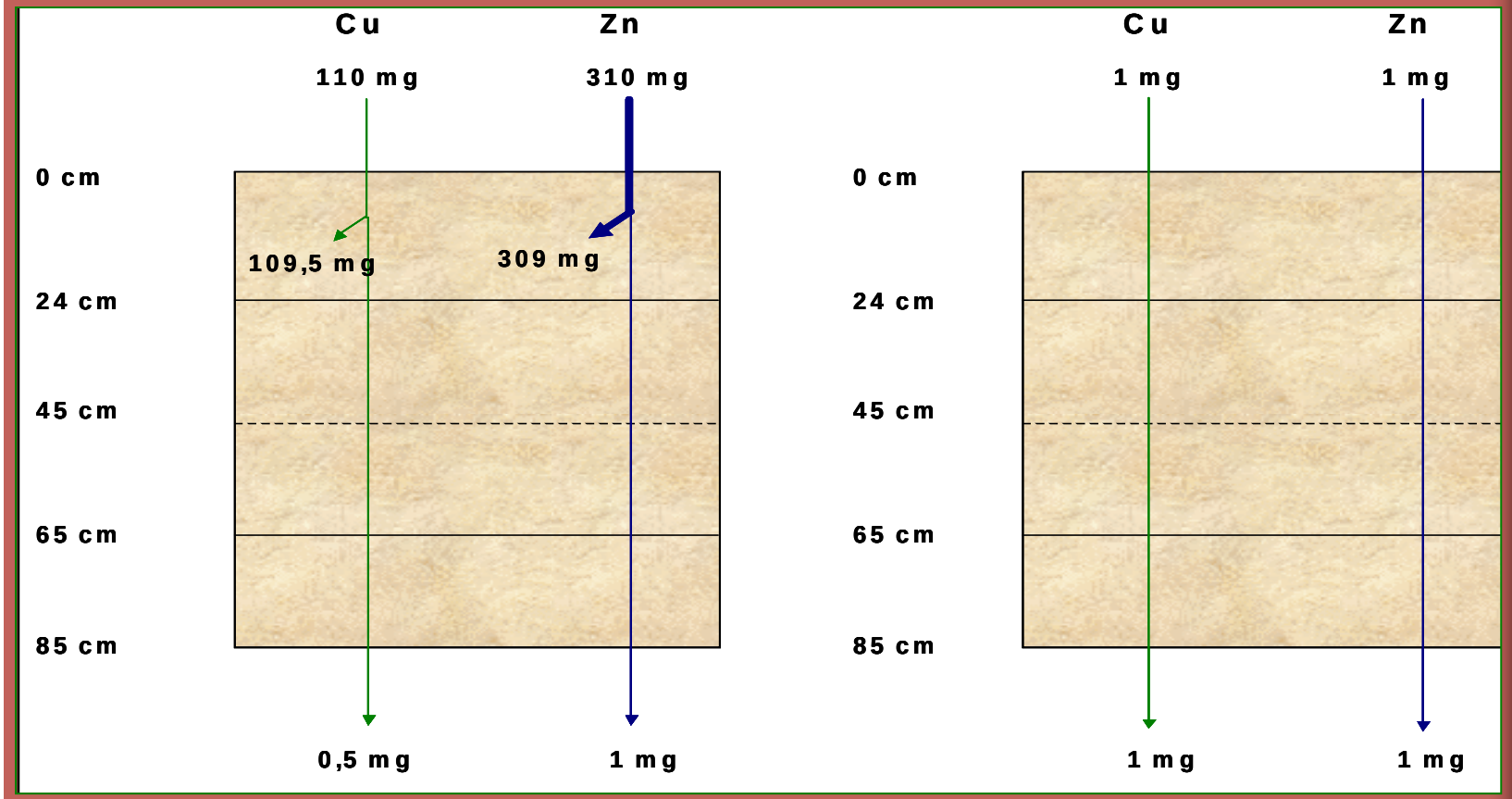
Thank you for your attention



Results

Retention and fluxes of Cu^{++} and Zn^{++}

Amended with pig manure



Control

All copper and zinc were adsorbed in the first horizon of the soil